

A FURTHER NOTE ON THE DIURNAL VARIATION OF
LEVEL AT KIMBERLEY.

BY J. R. SUTTON, ScD., F.R.S.S.Af.

(Read July 20, 1910.)

I have made a number of experiments during the past few months with the object of determining whether the diurnal oscillation of level is by any chance wholly or in part of photo-electrical origin; since, for reasons already stated, neither the distortion of the crust by heat and cold, nor the movements of subsoil water, nor the variation of load set up by the diurnal march of barometric pressure, seem to be competent to produce more than a small portion of the oscillation.* The results obtained so far are conflicting; while some have appeared to support the idea, others do not. The investigation, which is being continued as occasion offers, will be described later on, provided it yields anything definite and succeeds in reconciling the discrepancies.

My meteorological observations are not in disagreement with some kind of photo-electric theory of the diurnal oscillation of level. Seeing, nevertheless, that the earth's surface at Kimberley is scarcely ever at rest—the level being depressed north, south, east, and west almost unceasingly—no great amount of success is to be anticipated in disentangling the elements that really matter from those that do not. A heavy shower of rain, for example, will set up very large disturbances of level lasting many days, and interfering considerably with the diurnal oscillation. The passage of a barometric depression also has its own disturbing influence, which may be added on occasion to that of the rain. The following numbers show the daily averages of the hourly values of the deviation, to the west of the datum line, of the stylus of the horizontal pendulum,

* "Preliminary Note on the Diurnal Variation of Level at Kimberley," Trans. R.S.S.A., July, 1909.

following a heavy rain over Kimberley (5 inches in 12 hours) on March 20, 1910 :—

TABLE 1.

DAILY AVERAGE DEVIATION OF THE HORIZONTAL PENDULUM TO
THE WEST.

| | |
|----------------|----------|
| March 20 | 40·4 mm. |
| 21 | 37·7 |
| 22 | 26·3 |
| 23 | 18·8 |
| 24 | 14·5 |
| 25 | 10·3 |

This indicates a great depression of the east end of the level, due no doubt to the fact that a great deal of the storm water both ran directly off the ridge on which Kimberley is built as well as percolated downwards to the lower land eastwards, thus increasing the load and depressing the level on the side where it settled. Later on there was a gradual recovery. The pendulum, being reset to somewhere near its first value, recorded the following daily average readings :—

TABLE 2.

DAILY AVERAGE DEVIATION OF THE HORIZONTAL PENDULUM TO
THE WEST.

| | | | | | |
|---------------|----------|--------------|----------|---------------|----------|
| March 26..... | 43·2 mm. | April 3..... | 44·1 mm. | April 11..... | 55·8 mm. |
| 27..... | 43·1 | 4..... | 44·7 | 12..... | 56·1 |
| 28..... | 41·2 | 5..... | 44·4 | 13..... | 56·3 |
| 29..... | 40·8 | 6..... | 44·6 | 14..... | 56·4 |
| 30..... | 41·1 | 7..... | 47·3 | 15..... | 57·2 |
| 31..... | 41·2 | 8..... | 48·4 | 16..... | 58·6 |
| April 1..... | 42·8 | 9..... | 49·8 | 17..... | 60·1 |
| 2..... | 43·7 | 10..... | 51·5 | 18..... | 60·4 |

It appears, therefore, that the movement of the pendulum to the east lasted ten days, the recovery to the west taking at least twice as long.

To show the effect of the passage of a barometric depression upon the level, forty-four fairly typical and well-defined depressions were selected, and the average barometric pressure on five successive days—the third of

which is the day of least pressure—have been compared with the daily ranges of the pendulum from east to west for the same days. The following are the results:—

TABLE 3.

SHOWING THE EFFECT OF BAROMETRIC PRESSURE UPON THE DIURNAL RANGE OF THE HORIZONTAL PENDULUM.

| Day | Barometer. Mean. | H.P. Range. Mean. |
|-------------|---------------------|----------------------|
| Day 1 | 26·129 inches | 5·9 mm |
| 2 | 26·058 | 5·8 |
| 3 | 25·987 | 3·9 |
| 4 | 26·075 | 4·4 |
| 5 | 26·133 | 6·9 |

The mean daily range of the pendulum being 5·5 mm., it appears that when the barometer is lowest during the passage of a depression the range is 71 per cent. of the mean, whereas in the wake of the depression the range rises to 125 per cent.* The state of the sky is conceivably responsible for a large part of this difference.†

Table 4 shows the mean results of a comparison between various meteorological elements and the range of the horizontal pendulum. It is got (1) by arranging the daily duration of sunshine in order of magnitude each month, together with the corresponding values of earth temperature range at a depth of 1 inch; earth temperature maximum; maximum in the sun (black bulb *in vacuo*); range of barometric pressure; and range of the horizontal pendulum from east to west. (2) By dividing the monthly sets thus arranged into threes, each including as nearly as possible the same number of days, one set including all days with little sunshine, another with a medium amount, and the third set with a great deal. (3) By taking the annual averages of each of the three sets.

* This is the only relationship between the height of the barometer and the movement of the pendulum that I have been able to detect in anything like a definite way. That the pendulum at Kimberley does not deviate in any marked fashion from the centre of an approaching depression may be due to the fact that our storms usually travel from SW. to NE., and therefore cannot affect the gradient at right angles to the meridian to the same extent as they would if they travelled from W. to E. Probably, however, the views set forth by Dr. Klotz (Report of the Chief Astronomer for 1907–8, Ottawa, 1910) will make it necessary to reconsider the whole question of the relation between the variations of atmospheric pressure and level.

† The amount of cloud increases gradually as a depression approaches, and decreases rapidly as the depression passes away.

TABLE 4.

METEOROLOGICAL ELEMENTS COMPARED WITH THE CORRESPONDING RANGES OF THE HORIZONTAL PENDULUM.

| | Cloudy Days. | Medium Days. | Clear Days. |
|----------------------------------|-----------------|-----------------|----------------|
| Mean duration of sunshine *..... | 387 | 634 | 699 minutes |
| Range of earth temperature | 47 | 58 | 61 degrees |
| Maximum of earth temperature ... | 98 | 106 | 108 " |
| Maximum in the sun | 138 | 139 | 138 " |
| Range of pressure | 26·087 | 26·098 | 26·088 inches |
| Range of pendulum | 4·7 | 5·9 | 6·3 mm. |
| Number of days | 266 | 293 | 288 days |

It appears from this that the range of the pendulum increases as the daily duration of sunshine increases. The same range is evidently independent of the variation of the diurnal range of pressure, and also of the direct heating power of the sun so far as the black bulb *in vacuo* is competent to measure it. That the range of earth temperature should depend upon the duration of sunshine is no more than would be expected, seeing that under a clear sky nocturnal cooling goes on very rapidly. It is not easy to see, however, why the maximum temperature just under the surface of the ground should be, on the whole, highest under clear skies. According to the indications of the black bulb, the greatest heating effect accompanies a sky about one-half clouded, and a very high temperature on the black bulb is as a rule accompanied by a high temperature of the surface soil. But of course the black bulb attains a maximum in a very few minutes, whereas the ground takes time to warm up, as shown by the fact that the mean maximum for the day at a depth of 1 inch occurs somewhere near $1\frac{3}{4}$ h. p.m.

Table 5 gives the results of a comparison between the range of temperature of the surface soil, the duration of sunshine, and the mean daily range of the horizontal pendulum, arranged in sets according to the magnitude of the range of earth temperature.

TABLE 5.

RANGE OF EARTH TEMPERATURE AND DURATION OF SUNSHINE COMPARED WITH THE CORRESPONDING RANGE OF THE HORIZONTAL PENDULUM.

| | Cloudy Days. | Medium Days. | Clear Days. |
|---------------------------------|-----------------|-----------------|----------------|
| Range of earth temperature..... | 43 | 57 | 66 degrees |
| Mean duration of sunshine | 464 | 615 | 657 minutes |
| Range of pendulum | 4·7 | 5·9 | 6·4 mm. |

* Photographic record.

This arrangement gives the same values for the average daily swing of the pendulum, but it shows a smaller range of earth temperature on cloudy days, and a greater range on clear days than the arrangement of Table 4. On the other hand, it shows more sunshine on the cloudy days and less on the clear days than that Table does.

It seems to follow from this relation between the diurnal oscillation of level (as shown by the horizontal pendulum), the duration of sunshine, and the range of temperature of the surface soil, that if the oscillation is of photo-electric origin then it must depend upon the energy of waves of fairly long wave-length, *i.e.*, upon waves that are effective as heat rays rather than upon the more strictly actinic rays.